Feasibility Study for the Construction of Medium Strength Magnetic Fields for Studies in the Mechanical Behavior of Materials

by

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The object of this project was to determine the feasbibility of and to initiate research in the mechanical behavior of materials in the presence of low-to-medium strength magnetic fields. Such research demanded familiarization with past and present work, as well as some facility for performing controlled tests. Various articles were secured (as catalogued in the list of reference). Concerning the interaction of magnetic field and plastic flow, the conclusion derived from the literature survey was that no major experimentation had been performed and reported in this field. Thus, to serve the second purpose of this project, two medium strength electromagnetic field structures were considered:

1) A solenoid type field to produce a magnetic field colinear with the direction of the applied stress.

2) A solid core structure to produce a transverse field. With these two proposed field devices, an exploratory study of the effects of magnetic fields on material behavior could be performed.

Background material for this study consisted of numerous articles and books as well as several published bibliographies on the subject of electromagnetic phenomena.

Two designs were adopted for construction:

1) The solenoid type field was to be used to study the effects of a magnetic field colinear with an applied stress. The construction of this field used a piece of copper foil 120 feet long and 12 inches wide. The foil was 0.020 inches thick. The design can best be illustrated in the actual steps which were used:

Step A. The first decision was related to the core material. The core had to be hollow and should possess the same permeability as air, for reasons of centering the magnetic flux in the central volume of the core and not in the core-support material itself. The material should be strong enough to provide mechanical support for the copper foil and a good conductor of electricity. One material with these qualifications was aluminum. The final design of the aluminum pipe which was used is shown in Figure 1.

Step B. The second decision related to the physical dimensions of the copper foil. It was decided that two solenoids could be constructed from the available material. Thus, on this basis the copper foil was cut as shown in Figure 2 to yield two pieces of the same size and weight.

Step C. Construction consisted of devising a means of winding the foil on the aluminum pipe. After devising a hand cranking device with centering-spools, the foil was wound on the center of the aluminum pipe. The 2 inch end of foil was fastened to the pipe and the symmetrically wound field was made as shown in Figure 3. The insulation between the layers of copper-foil was thin mylar plastic. The resistance of the final coil was to be approximately 0.01 ohms.

2) The second design was a solid core air-gap type structure. This design required the flux lines transverse to a controlled air gap and was to be used to study the transverse effects of the magnetic field on a material under a longitudinal uniaxial stress. The construction consisted of:

Step A. A wire large enough to carry approximately 50 amps was obtained (50 amps would insure saturation of the solid core, and about 500 feet of No. 8 solid copper wire was obtained with a current carrying capacity of 68 amps).

Step B. Pure iron saturates at about 21 kilogauss. Other materials (cobalt, etc.) would raise the saturation point and thus, the air gap field strength can potentially be about 25 kilogauss. Cobalt is relatively expensive and was not immediately available. Thus a very low carbon iron was secured with a saturation point of approximately 19 kilogauss.

Step C. A design which would permit adjustment of the air-gap and keep the amount of materials to a minimum was selected. The reluctance of the flux paths was also kept to a minimum. The design of the component parts and the finished structure are shown in Figures 4 and 5. (The copper wire was wound around the core with 550 turns).

A dry disk rectifier (DC welding unit) with potential of 28 vdc at 200 amperes was used for the power supply. The output current contained a large ac ripple and was not well regulated.

There are two proposed uses for these two structures. The first consists of placing materials in the magnetic field and, by the use of a table model Instron testing machine the effects of magnetic fields on the stress-strain diagram are measured. The second use is to melt a non-magnetic material and then let in solidify in the magnetic field. In the first of these experiments (performed with the iron-core structure) no conclusions were reached because of interactions of the magnetic field and the testing machine. The second of these showed little or no effect on the resulting hardness of a cast solder (Pb-Sn alloy).

Several recommendations as to future use of these structures are presented:

1) A means of cooling both magnetic circuits in order to reduce power losses, increase current capabilties, and improve the saturation points of the core material should be designed.

2) A more efficient dc power source or either filter the present source in order to remove unwanted ac voltage ripples should be incorporated in the power supply.

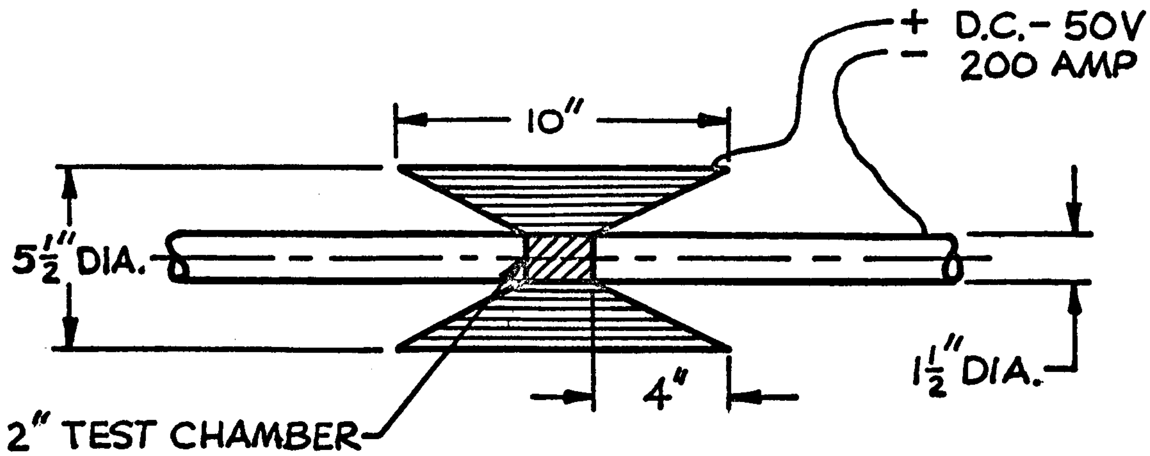
3) A higher saturation point material for the core of the solid core structure such as Permendur or Puron should be obtained.

4) Aluminum jaws on the gripping device of the Instron should be used to prevent unwanted forces acting on the load cell and the electronic control panel should be separated from the testing frame.

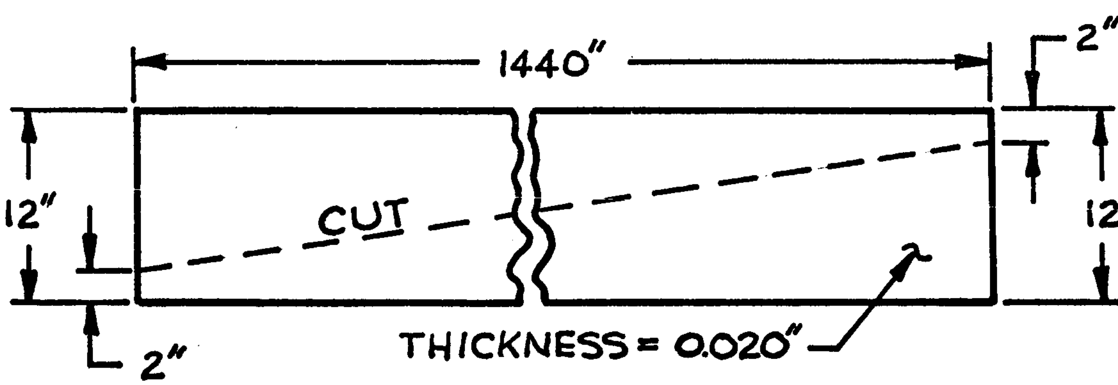
5) A superconducting solenoid having a 50 to 60 KG field would provide a much stronger field and should be obtained if this work is to continue.

Rate of Effort

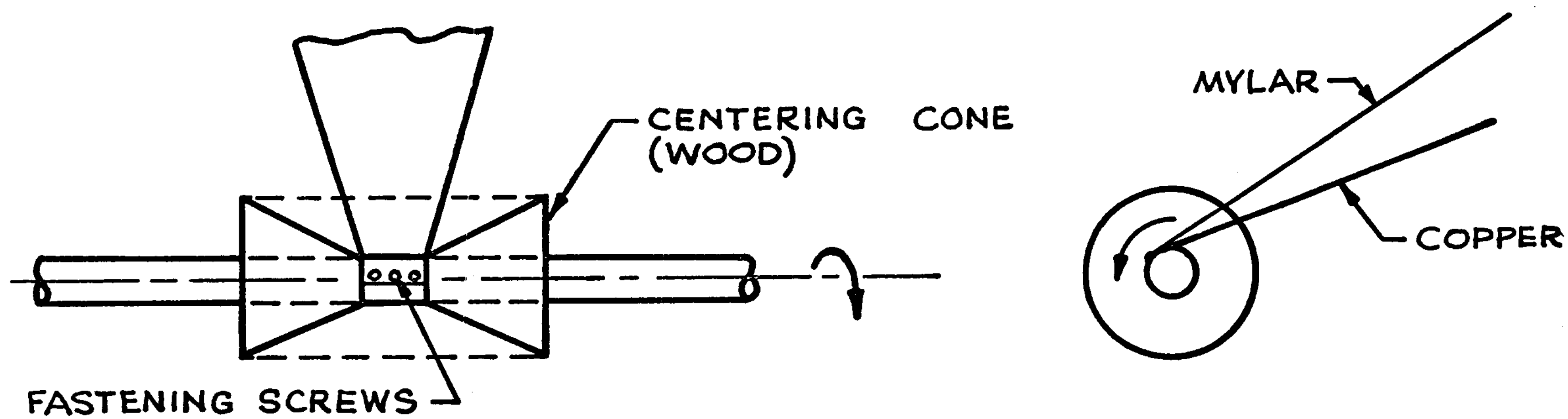
The amount of effort expended on this phase was 283 hours student assistant, 50 hours machinist, and 30 hours administrative.



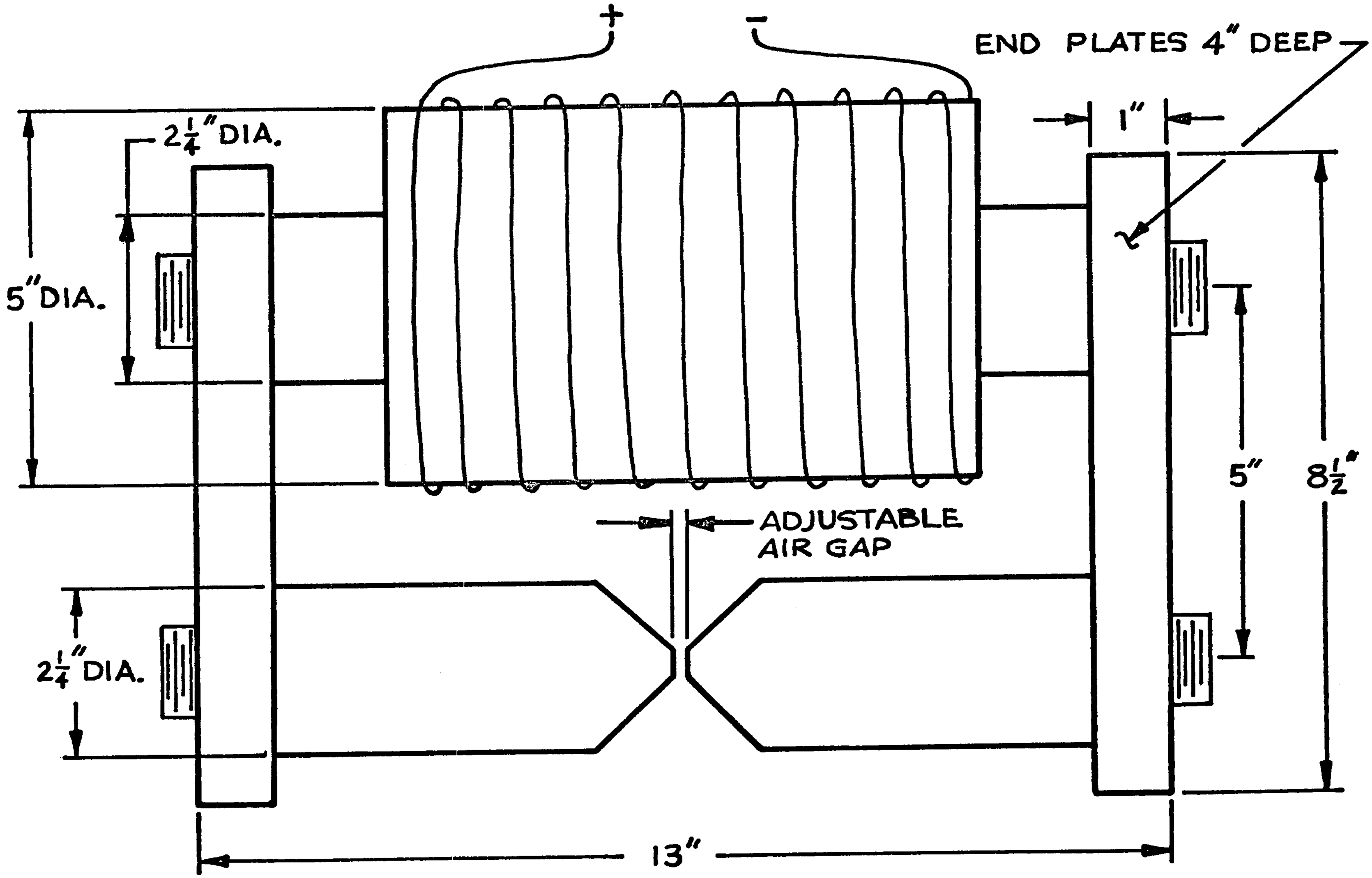
SECTION OF SHAPED FIELD SOLENOID
FIG. 1



SCHEMATIC OF METHOD OF SLICING FOIL ROLL
FIG. 2



SCHEMATIC OF COIL WINDING TECHNIQUE
FIG. 3



SCHEMATIC OF TRANSVERSE FIELD SOLENOID
FIG. 4

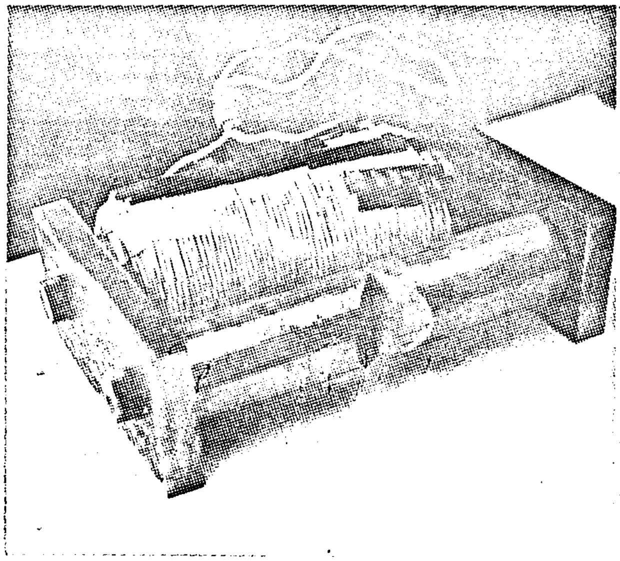
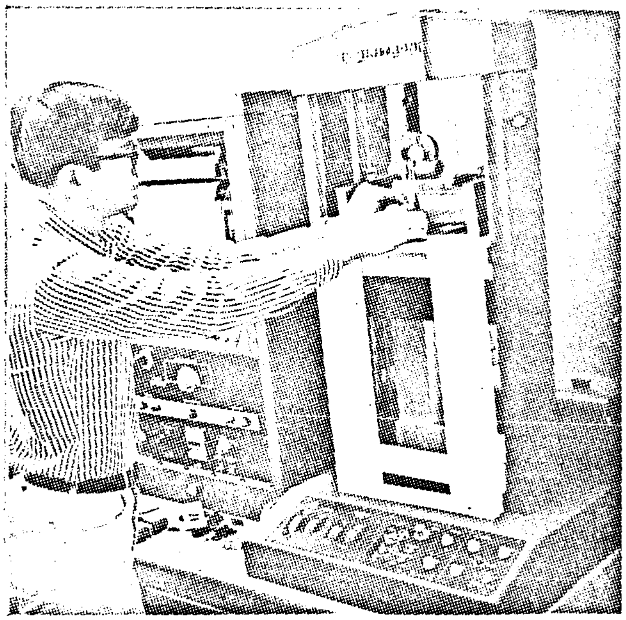


FIGURE 5

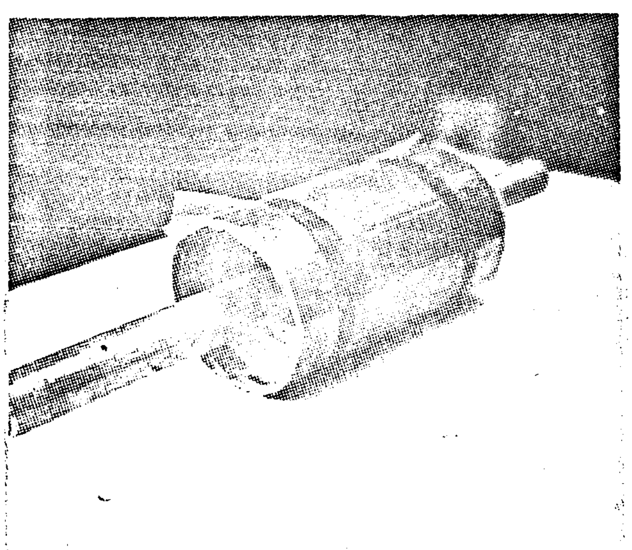
5A. Solid-Core Solenoid
Pole-Piece Opening
0.04" X 0.5" X 2"
Field Strength at 50 AMP
~~50~~ Kilogauss
19



5B. Solid-Core Solenoid

For Mechanical Testing

The Instron Testing Machine is shown set up for performing tension tests, (Magnetic axis is transverse to stress axis).



5C. Shaped-field Solenoid

Size of Test Chamber =

1 3/8" dia. X 2" Long

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